

Project Report: Re-tracing Steps Towards a Habitable World: The Biogeochemical Evolution of Sulfur on the Early Earth.

Project Investigator:

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Project Progress

**Mass-independent isotope effects in sedimentary rocks by ion microprobe analysis.*

We and our NAI collaborators at UCLA have reported on a new high-resolution technique using the UCLA Cameca ims1270 ion microprobe in multicollection mode to investigate mass-independent (^{33}S) sulfur isotope variability in a variety of Precambrian sediments including the oldest known rocks of sedimentary origin (Mojzsis *et al.* (2003) *Geochim. Cosmochim. Acta*: 67(9), 1635–1658). We have now moved beyond the feasibility stage and are actively engaged in measuring hundreds of samples spanning the “Great Oxygenation Event” between ~2.47 and 2.33 Ga that irreversibly oxidized the surface zone of the planet.

**Discrimination between preservation of original igneous zircon populations and inherited grains.*

We described a method whereby the chemistry of a complex metamorphic rock coupled with U/Th ratios in zircon from the same rock permits direct assessment of zircon “inheritance” vs. true igneous ages. The technique has been used to resolve outstanding problems in the genesis of lower crustal rocks that stabilize the continents (Mojzsis *et al.* (2003) *J. Geol.* 111(4), 407–425) as well as overcome the long-standing problem of interpreting primary “igneous” ages from overprinted “metamorphic” ages in the oldest rocks. This new methodology is being extended to samples of described pre-3.7 Ga rocks worldwide (Acasta gneisses, Canada; Manfred Complex, Australia; etc.)

Highlights

- Our work on mass-independent fractionation of sulfur isotopes in ancient sediments contributed data that (i) place limits on the geochemical record of the transformation of the surface zone to an oxygen-rich environment between 2.5 and 2.3 billion years ago,

possibly at the expense of methane (*Mojzsis, S.J. (2003) Nature 425 (6955), 249–251 doi:10.1038/425249a*); (ii) described a means to investigate traces of early microbial metabolisms that utilized sulfur as an oxidant and provided data proposing the appearance of this metabolic style in the early Archean; and (iii) formulated a novel way of identifying a sedimentary origin of rocks in highly metamorphosed terranes transcending different interpretations of conventional trace element arguments.

- Research on Th/U coupled with geochronology of zircon has traced the metamorphic transition from amphibolite to the granulite facies that dominates the geologic history of all rocks that are more than 3.7 billion years old. The importance of these studies rests in our new ability to deconvolve complex metamorphic overprinting on original igneous crystallization ages. We can now describe the metamorphic history of the oldest terranes and better glean clues concerning the habitability of the early Earth.

Roadmap Objectives

- **Objective No. 1.1:** Models of formation and evolution of habitable planets
- **Objective No. 3.1:** Sources of prebiotic materials and catalysts
- **Objective No. 4.1:** Earth's early biosphere
- **Objective No. 4.3:** Effects of extraterrestrial events upon the biosphere
- **Objective No. 5.2:** Co-evolution of microbial communities
- **Objective No. 5.3:** Biochemical adaptation to extreme environments
- **Objective No. 6.2:** Adaptation and evolution of life beyond Earth
- **Objective No. 7.1:** Biosignatures to be sought in Solar System materials
- **Objective No. 7.2:** Biosignatures to be sought in nearby planetary systems

Field Expeditions

Field Trip Name: Jack Hills

Start Date: June 2003	End Date: July 2003
Continent: Australia	Country: Australia
State/Province:	Nearest City/Town:
Latitude:	Longitude:
Name of site(cave, mine, e.g.): Narryer Gneiss Complex	Keywords:

Description of Work: Western Australia: (June–July, 2003) fieldwork in the Jack Hills region of the Narryer Gneiss Complex to investigate further occurrences of the oldest known terrestrial materials (pre–4.0 billion year old zircons) and the North Pole region, Pilbara craton (with Dr. M. Van Kranendonk) to study the oldest well–preserved sediments.

Members Involved:

Field Trip Name: NAI field workshop

<i>Start Date:</i> July 2003	<i>End Date:</i> July 2003
<i>Continent:</i>	<i>Country:</i>
<i>State/Province:</i>	<i>Nearest City/Town:</i>
<i>Latitude:</i>	<i>Longitude:</i>
<i>Name of site(cave, mine, e.g.):</i> Barberton Greenston Belt	<i>Keywords:</i>

Description of Work: South Africa: *July, 2003) graduate student Dominic Papineau participated in the NAI field workshop to the Barberton Greenston Belt.

Members Involved: